METHOD TO MAKE SINTER-HARDENED POWDER METAL PARTS WITH COMPLEX SHAPES

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The invention pertains to the field of metallurgy. More particularly, the invention pertains to a method of producing a material from a metallurgical powder comprised of iron, carbon, nickel, molybdenum, and a combination of chromium, copper, manganese, and silicon.

DESCRIPTION OF RELATED ART

Sinter hardening is a process used to produce a high martensite-content material without using a conventional heat treatment process, such as batch heat-treating or induction hardening. The sinter hardening process comprises the steps of sintering the compact at an elevated temperature followed by rapidly cooling the compact at the end of sinter furnace hardening to induce martensite transformation.

There have been patented a number of methods to produce sinter-hardened powder metal parts which include a pre-sintering step.

Pre-sintering of metallurgical materials has been reported by Umeha *et al.* (U.S. 4,595,556), Method For Manufacturing Camshaft, issued June 17, 1986. Umeha *et al.* disclose a method for producing members for fitting onto camshafts. After the pre-sinter step, the piece can be properly positioned on the shaft prior to sinter hardening. The compact is fifty percent axially shorter than the pre-sintered compact.

Saka *et al.* (U.S. 5,049,183), Sintered Machine Part And Method, issued September 17, 1991, discloses a method similar to Umeha *et al.*, in which the pre-sinter step allows for improved precision of product size. The compact is repressed after the pre-sinter. Such a method would be particularly applicable for producing synchronizer hubs for motorcars.

Seyrkammer (U.S. 5,659,873), Method Of Producing A Cam For A Jointed Camshaft, issued August 19, 1997, also describes a method, which includes a pre-sintering step. This method is used to produce a cam for a jointed camshaft. The pre-sintering step allows for the cam to be reworked to the desired contour, which may be lost during quenching and tempering.

Plamper (U.S. 5,659,955), Method Of Making Powder Metal Helical Gears, issued August 26, 1997, uses pre-sintering to produce a powder metal blank, which can be cold-rolled to make a helical gear with a helix angle greater than 35 degrees. Standard powder metal compaction processes can not be used to make helical gears of a large helix angle.

Shivanath *et al.* (U.S. 5,729,822), Gears, issued March 17, 1998, also pre-sinter a gear where the gear is rolled prior to the final heating and carburizing in a vacuum furnace. This method produces a transmission gear with a hard durable surface and a tough, fracture-resistant core to maximize the bending endurance of the transmission gear.

Shivanath *et al.* (U.S. 5,881,354), Sintered Hi-Density Process With Forming, issued March 9, 1999, describes a process for formation of high-density articles, where the pre-sintered compact undergoes spheroidization prior to a secondary heat treatment. The spheroidization step involves warming up the compact and sizing or coining it. This process decreases surface oxidation to improve the fatigue endurance of the sintered part.

Finally, Cadle *et al.* (U.S. 6,148,685), Duplex Sprocket/Gear Construction and Method of Making Same, issued November 21, 2000, use two metallurgical powder mixtures, one for the teeth and one for the body, to produce a sprocket. The two powder alloys have properties tailored for local functional requirements of the final product. The sintered body may be machined.

In engine and transmission applications, some sprockets have multiple rows of teeth, which can not be produced by simply compaction. Secondary machining is required. The heat treatment done after machining is usually induction hardening or batch heat treating. While the prior art addresses limited ways in which powder metal parts can be shaped by including a pre-sintering step, there is a need in the art for an efficient method of producing powder metal parts of more complex shapes.

SUMMARY OF THE INVENTION

A method of producing parts from powdered metals is disclosed, comprising the following steps. A metallurgical powder is provided, consisting of iron, 0.3-1.0 weight percent carbon, 0-4 weight percent chromium, 0-3 weight percent copper, 0.5-1.5 weight percent molybdenum, 0.5-4.5 weight percent nickel, 0-1.0 weight percent manganese, and 0-1.5 weight percent silicon. Metal powders are made by atomization and mixing. The powder metal parts are made by compacting, pre-sintering, profile/form grinding, sinter furnace hardening, and secondary operations. Profile/form grinding generates profiles, which can not be formed by compaction tooling, such as undercut. The specific pre-sinter cycle makes parts strong enough to withstand profile grinding but soft enough for easy grinding and prolonged grinding tool life. Powder metal parts made by this invention are also disclosed.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 shows a process flow chart to make sinter-hardened metal parts with complex shapes.

DETAILED DESCRIPTION OF THE INVENTION

Metal powders are made by atomization and mixing. The particulate materials consist of iron, 0.3-1.0 weight percent carbon, 0-4 weight percent chromium, 0-3 weight percent copper, 0.5-1.5 weight percent molybdenum, 0.5-4.5 weight percent nickel, 0-1.0 weight percent manganese, and 0-1.5 weight percent silicon. Table 1 lists the composition ranges for the particulate materials. The powder possesses good sinter-hardening capabilities.

Table 1: Composition Ranges of Metallurgical Powders for Complex Shape Formation

Element	**Fe**	**C**	**Cr**	**Cu**	**Mo**	**Ni**	**Mn**	**Si**
New Powder	Balance	0.3-1.0	0-4	0-3	0.5-1.5	0.5-4.5	0-1.0	0-1.5

The process flow chart is shown in Figure 1. The metallurgical powders are compacted (1) with a compaction pressure of 30 to 65 tons per square inch with a green density of 6.5 to 7.25 grams per cubic centimeter. The green parts are pre-sintered (2) at a temperature from 1400 to 2000 degrees Fahrenheit. Pre-sintering time is from 20 to 60 minutes. Cooling rates vary from 10 degrees Fahrenheit per minute to 120 degrees Fahrenheit per minute to produce various microstructures such as Pearlite, Ferrite + Pearlite, and Bainite. When the cooling rate is greater than 120 degrees Fahrenheit per minute, Martensite, which is hard to machine, forms. Slow cooling (10 degrees Fahrenheit per minute) produces primarily a Pearlite microstructure. Spheroidized Pearlite is best for machining. The compact is cooled to ambient or nearly ambient temperatures. Microstructure can be precisely achieved through control of pre-sintering temperature and cooling rate. As a result of the pre-sinter, the powder metal parts gain strength to make them strong enough for profile/form grinding (3). The specific pre-sinter cycle also makes the particle hardness of the parts low to prolong the life of the grinding tool used during the profile/form grinding step.

Profile/form grinding utilizes super-abrasive tools to generate profiles and detailed geometry. The process is also called Super Abrasive Machining (SAM). Profile/form grinding is done after pre-sinter to produce various complex shapes such as multiple rows of teeth and undercut teeth, which are difficult to make by conventional powder metal compaction methods and single point machining. The complexity of the shape is limited only by the size and precision of the profile and form grinding equipment.

After grinding, parts are sinter furnace-hardened (4). The sinter furnace hardening conditions are as follows: sintering temperature of 2000 degrees Fahrenheit to 2400 degrees Fahrenheit for 20 to 80 minutes, with a cooling rate of 120 to 450 degrees Fahrenheit per minute. The final heat treatment is capable of producing greater than 90 percent Martensite, with a small amount of retained Austensite, Pearlite, and Bainite in the final powder metal part. Tempering, deburring, and other secondary operations (5) are optional depending upon final performance requirements.

This invention utilizes a special pre-sintering cycle (2) before profile/form grinding (3) and sinter furnace hardening (4). Pre-sintered parts are strong enough for profile/form

grinding without breaking or chipping. Profile/form grinding (SAM) generates profiles and detailed geometry in a single operation. This method allows profile/form grinding to be done using less pressure and greater feed speed than when grinding regularly sintered parts. The invention also avoids the problem of grinding hardened powder metal parts.

Example: Powdered metal Gemini sprockets used in a transfer case

The Gemini sprocket has two rows of teeth with a phase angle between the rows of teeth. The Gemini sprocket design is disclosed in U.S. Patent No. 5,427,580, Phased Chain Assemblies, issued to Ledvina *et al.* on June 27, 1995. The sprocket is part of a chain-drive system used in an automotive front-wheel drive transmission. An advantage of the Gemini sprocket is reduced noise during operation. Considerations in material development include hardness/wear resistance and good hardenability.

In one embodiment of the invention, the material containing iron, 2 weight percent copper, 0.8 weight percent carbon, 1.4 weight percent nickel, 1.25 weight percent molybdenum, and 0.42 weight percent manganese is pressed at a compaction pressure of 45 tons per square inch and pre-sintered at 1650 degrees Fahrenheit for 30 minutes. The pre-sintered parts are cooled at 25 degrees Fahrenheit per minute. The parts are then ground with a super-hard formed wheel to create two rows of teeth with a groove in between the rows. After profile/form-grinding, the parts are sinter furnace hardened at 2070 degrees Fahrenheit for 30 minutes. After sinter furnace hardening, the parts are cooled at a rate of 150 degrees Fahrenheit per minute. As a secondary operation, deburring was performed.

Accordingly, it is to be understood that the embodiments of the invention herein described are merely illustrative of the application of the principles of the invention. Reference herein to details of the illustrated embodiments is not intended to limit the scope of the claims, which themselves recite those features regarded as essential to the invention.